Corn Grain and Liquid Feed as Non-Fiber Carbohydrate Sources in Diets for Lactating Dairy Cows: Digestibility Trial

Andrea M. Eilenfeld
Honors Research Thesis
Research Advisor: Dr. Maurice Eastridge, Ph.D
Department of Animal Sciences
The Ohio State University
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Abstract

We predicted that adding a sugar-based liquid feed (LF) additive would improve the non-structural carbohydrate (NSC) digestibility of corn grain ground coarsely compared to finely ground corn. The NSC sources are necessary in dairy cattle diets because they provide readily available energy that can enhance rumen microbial activity and forage utilization. This study used five rumen cannulated cows milked twice daily at The Ohio State University's Waterman Dairy Center in a 5 x 5 Latin square design to test for total tract digestibility of neutral detergent fiber (NDF) and organic matter (OM), as well as ruminal concentrations of ammonia and volatile fatty acid (VFA). All diets contained a constant 24% corn silage, 16% alfalfa hay, and 6% grass hay that were adjusted to maintain 36% NDF, 20.3% forage NDF, and 36% NSC. The control diet contained steam flaked corn (SFC) and the other diets contained either finely (FGC) or coarsely ground corn (CGC), factorialized with or without 3.5% LF (Quality Liquid Feeds, Dodgeville, WI). Treatment periods consisted of two weeks, and chromic oxide was dosed via the rumen as a digestibility marker. The LF increased butyrate with FGC but not CGC. Finer particle size and SFC reduced ($P < 0.05$) ruminal ammonia concentrations, and the finer particle size reduced ruminal pH. There were no treatment effects on digestibilities of dry matter (65.9%), OM (67.7%), and NDF (54.9%). Milk fat (3.51%) and protein (2.85%) were similar among diets, but milk urea nitrogen was lower with finely ground corn. The SFC and FGC seemed to be more rapidly fermented in the rumen, without adversely affecting intake or digestibility. Liquid feed appeared to be more beneficial with FGC than CGC.

Introduction and Problem Identification

Today, dairy farmers are faced with a choice of feeding more digestible, highly processed and expensive corn products or less digestible dry ground corn products as non-structural carbohydrate (NSC) sources to their production herds. The NSC, such as starch and sugar, are necessary in dairy cattle diets because they provide readily available energy that can enhance rumen microbial activity and forage utilization. The more efficiently the rumen ferments feed, the more efficiently milk will be produced (Firkins et al., 2001). It has also been studied that decreasing the particle size of corn greatly affects the true ruminal digestibility of NSC (Callison et al., 2001). Firkins et al. (2008) discussed that the addition of a liquid feed in conjunction with a white grease product also correlates into higher production of milk, milk fat percentage, and milk protein percentage, which would have positive effects on the efficiency of milk production.

The main focus of this research project was to determine if adding a liquid feed to a ground corn product could improve animal performance and digestibility when compared to a highly processed product, such as steam-flaked corn. This project had the goal of reducing the costs of grain processing by dairy farmers while still providing adequate NSC digestibility with the addition of a liquid feed product. In addition, we anticipated that the dry matter intake (DMI) and ruminal fermentation characteristics of the dairy cattle in our dietary treatment program would be more enhanced by adding the liquid feed to the coarsely ground corn diets compared to the finely ground corn diets.

This study focused on five cannulated dairy cows at The Ohio State University's Waterman Dairy Center in a 5 x 5 Latin square. A parallel study with approximately 60 dairy cows, also at the Waterman Dairy Center, was conducted by other department researchers using the same dietary treatments in order to measure the effect of corn processing and liquid feed on milk production and DMI.

We proposed that the liquid feed additive could provide a highly digestible carbohydrate source that increases NSC digestibility in ground corn treatments without depressing DMI. This would, in turn, affect the overall production performance of the dairy cows, and if adding the liquid feed supplement could improve NSC digestibility and DMI with ground corn products, doing so would reduce feed processing costs to dairy farmers.

Hypothesis

The hypothesis was that adding a liquid feed will improve NSC digestibility, such as sugars and starch, and/or improve DMI in diets with ground dry corn and to a greater extent with coarsely ground (CGC) than finely ground corn (FGC).

Procedures and Methodology

Prior to beginning this project, an in-situ trial with the corn sources was completed. This project included three types of corn grain: steam-flaked corn (SFC), FGC with an average particle size of 0.8 mm diameter, and CGC with 1.9 mm diameter. Porous dacron bags containing the corn grain were placed inside the rumen of three rumen cannulated cows with two replications per cow. Bags were removed at 2, 4, 8, 12, 24, 36, and 48 hr to measure the rate and extent of degradation of the corn particles in the rumen.

Before beginning the treatment trials, each cow must have calved and been at least 60 days into her lactation cycle in order to start the dietary treatment. In a 5 x 5 Latin square design, each of the five rumen cannulated cows was fed one of the following diets in periods of two weeks: a control (36% NSC, 20% forage NDF) diet with steam flaked corn (SFC), 36% NSC with ~800 micron dry ground corn (fine ground), 36% NSC with ~800 micron dry ground corn with 3.5% liquid supplement, 36% NSC with ~1800 micron dry ground corn (coarse ground), and 36% NSC with ~1800 micron dry ground corn and 3.5% liquid supplement.

Each diet consisted of equal amounts of corn silage, alfalfa hay, and grass hay, with the liquid feed substituting for 3.5% of the concentrate mix in two of the diets (Table 1). The liquid feed used during this project was furnished by Quality Liquid Feeds (Dodgeville, WI) in addition to grant support. The liquid feed was 66% dry matter, and on a dry matter basis, contained 30.3% crude protein and 53% total sugar, resulting in 1.86% supplemental sugar in the diets containing the liquid feed.

Table 1. Ingredient composition (% of DM) of diets (alfalfa and grass hay levels were adjusted to maintain a targeted 36% NDF).[1]

Item	SFC	FGC	CGC	FGC + LF	CGC + LF
Corn Silage	24.0	24.0	24.0	24.0	24.0
Alfalfa Hay	16.0	16.0	16.0	16.0	16.0
Grass Hay	6.0	6.0	6.0	6.0	6.0
Concentrate	54.0	54.0	54.0	50.5	50.5
LF	0.0	0.0	0.0	3.5	3.5

[1]SFC = Steam flaked corn, FGC = finely ground corn, CGC = coarsely ground corn, and LF = liquid feed.

Chromic oxide was administered in the rumen on days three to 13 of each period. Chromic oxide is indigestible, and thus, chromium is used as a measure of digestibility. A known amount of chromium was fed (100 g/d of pellets containing 9.258% chromic oxide), and chromium was analyzed in the feces. Then, digestibilities of dietary components were calculated using the following equation: 100 - (100 x (% marker in feed / % marker in feces) x (% nutrient in feces / % nutrient in feed)).

Cows were housed in a tie-stall barn and were milked twice daily in a double-8 herringbone, rapid exit parlor. Feed intake and milk yield were recorded daily. Samples of feed offered, feed refused, and feces were taken for measurement of total tract digestibility of dry matter, organic matter, neutral detergent fiber (NDF), and nitrogen during days 10 through 14 of each period. Also, at the end of each period, rumen samples were taken at 3, 6, and 9 hours after the morning feeding and analyzed for pH and concentrations of VFA and ammonia. Milk samples were taken during four consecutive milkings during the second week of each period for measurement of fat, protein, and milk urea nitrogen (MUN). Body weights were taken weekly. Body condition scores (1 = thin, 5 = fat) of the cows were also assigned at the beginning of the project and at the end of each period.

The data were analyzed using the MIXED model procedure in SAS, with diet and period as fixed effects and cow as a random effect. The REPEATED measures procedure with SAS was used for ruminal pH, ammonia, and VFA data. The four contrasts utilized for the data were: **Liquid feed** (CGC, FGC vs CGC+QLF, FGC+QLF), **L** = P < 0.05, **l** = P < 0.10; **Particle size** (CGC, CGC+QLF vs FGC, FGC+QLF), **P** = P < 0.05, **p** = P < 0.10; **SFC vs dry corn** (SFC vs CGC, FGC, CGC+QLF, FGC+QLF), **S** = P < 0.05, **s** = P < 0.10; and **Interaction L vs P, LP** = P < 0.05, **lp** = P < 0.10.

Results and Discussion

Prior to beginning this project, we completed a 24 hour in-situ trial of the three particles sizes of corn, including finely ground corn (FGC), coarsely ground corn (CGC) and steam-flaked corn (SFC) to determine their degradability in the rumen. The particle sizes we chose for the CGC was approximately 1.9 mm and 0.8 mm for the FGC diet (Table 2). It was published by Callison et al. (2001) that ruminal and total tract digestibility are highly correlated and that by decreasing the particle size of corn, the true ruminal digestibility of NSC is greatly affected. Callison et al. (2001) used the same in-situ method to complete their work. In our study, there were statistical differences between the different particle sizes in the A Pool, or rapidly degraded section, and B

Pool, or slowly degraded section, with CGC having a significantly lower amount in the A pool and more in the B pool compared with the other corn grains, which is expected since the CGC is a much larger particle size. The rates of degradation (Kd) among the diets were similar, but extent of ruminal degradation (RD) within 24 h was from highest to lowest for FGC, SFC, and CGC.

Table 2. In-situ digestibility of steam flaked corn (SFC) and coarsely and finely ground corn (CGC and FGC, respectively).[1]

Corn Grain	A pool (%)	B pool (%)	C pool (%)	Kd (/h)	RD (%)	Lag (h)
CGC (1.9 mm)	6.08[a]	91.1[a]	2.82	0.052	43.1[a]	2.94[a]
FCG (0.8 mm)	15.42[b]	83.1[b]	1.45	0.057	53.6[b]	2.27[a]
SFC	11.51[c]	85.0[b]	3.52	0.043	50.1[c]	0.00[b]

[abc] Means in the same column differ (P < 0.05).
[1]Kd= Rate of degradation and RD = extent of ruminal degradation.

Dietary concentrations of DM, NDF, and ash in the diets were similar to target concentrations (Table 3). Crude protein (CP) was about 92% of target concentrations but still adequate given the high DMI.

Table 3. Dietary concentrations of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), and ash[1].

Item	SFC	FGC	CGC	FGC + LF	CGC + LF
DM, %	64.5	64.5	63.5	64.1	65.4
CP, %	16.3	16.5	16.3	16.4	17.0
NDF, %	36.3	36.1	37.6	38.2	36.6
Ash, %	6.67	7.07	7.11	7.21	7.46

[1]SFC = Steam flaked corn, FGC = finely ground corn, CGC = coarsely ground corn, and LF = liquid feed.

Finer particle sizes of corn reduced rumen pH (Table 4), which coincides with results that have been repeatedly proven in scientific experiments (Plascencia and Zinn, 1996). The pH for all treatments remained in a healthy range, thus there was no evidence of any adverse effects on rumen health. Russell et al. (1998) discussed that some bacteria use amino acid nitrogen as a method of improving their growth rates because it is a way of decreasing “energy spilling” or ridding the bacteria of ATP. Amino acid nitrogen is only beneficial, however, if the rate of carbohydrate fermentation is rapid and carbohydrates are provided in excess. It was found in this project that ammonia concentrations were lowered by both smaller particle sizes and by SFC. The more rapidly fermentable NSC likely improved microbial utilization of N, reducing ruminal ammonia concentrations and MUN concentrations reported in Table 5 (especially for the finely ground corn diet).

There are three main VFA produced in the rumen [acetate (A), propionate (P), and butyrate], all of which assist in various necessary functions to allow for the production of milk. We found that finer particle size of corn reduced the ratio of acetate to propionate (A:P) but increased the concentration of propionate. Also, the LF increased ruminal concentrations of butyrate with FGC but not CGC (Table 4), as the concentration of butyrate went from 10.4 to 11.7 moles/100 moles with the addition of the LF to the FGC, but remained fairly constant at an average of 11.1 moles/100 moles with the addition of the LF to the CGC.

Table 4. Rumen pH and ruminal concentrations of ammonia and volatile fatty acids (VFA; moles/100 moles).[1]

Item[2]	SFC	FGC	CGC	FGC + LF	CGC + LF
pH[P]	6.03	6.04	6.20	5.94	6.12
Ammonia, mg/dl[P,S]	9.28	10.18	12.28	11.17	11.53
Total VFA, mM	145	145	140	150	143
Acetate (A)	65.1	65.9	66.3	65.2	65.9
Propionate (P)[p,s]	20.6	20.5	19.3	19.8	19.5
Butyrate[L,LP]	10.9	10.4	11.0	11.7	11.2
Isobutyrate[P]	0.69	0.71	0.75	0.68	0.74
Valerate[L]	1.40	1.33	1.34	1.42	1.38
Isovalerate	1.29	1.18	1.27	1.21	1.26
A:P[p,S]	3.17	3.24	3.46	3.34	3.42

[1]SFC = Steam flaked corn, FGC = finely ground corn, CGC = coarsely ground corn, and LF = liquid feed.
[2]Contrasts: **Liquid feed** (CGC, FGC vs CGC+QLF, FGC+QLF), **L** = P < 0.05, **l** = P < 0.10; **Particle size** (CGC, CGC+QLF vs FGC, FGC+QLF), **P** = P < 0.05, **p** = P < 0.10; **SFC vs dry corn** (SFC vs CGC, FGC, CGC+QLF, FGC+QLF), **S** = P < 0.05, **s** = P < 0.10; and **Interaction L vs P, LP** = P < 0.05, **lp** = P < 0.10.

Firkins et al. (2001) found that processing corn to increase the ruminal degradability of starch generally decreased the neutral detergent fiber digestibility by a small increment. This project found that there were no treatment affects on total tract digestibilities of (65.9%), OM (67.7%), and NDF (54.9%), however (Figure 1).

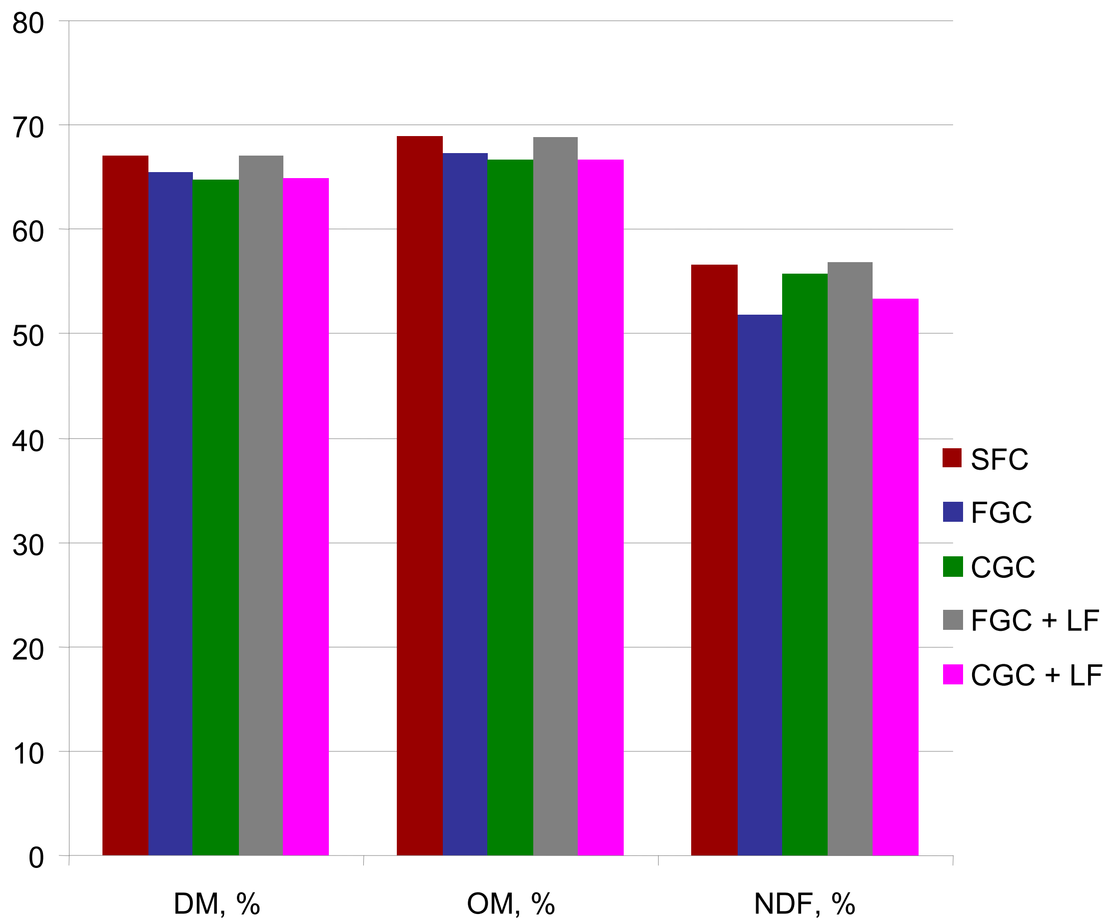

Figure 1. Total tract apparent digestibilities of dry matter (DM), neutral detergent fiber (NDF), and organic matter (OM); SFC = steam flaked corn, FGC = finely ground corn, CGC = coarsely ground corn, and LF = liquid feed.

The DMI of the cows involved in this project remained steady at an average of 24.6 kg/d. A study by Yu et al. (1998) explored the effects of different types of ground and processed corn on performance in lactating cows and found that cows fed diets with steam-flaked corn at a medium density had the highest milk yield of all the cows in among the treatment programs. Our data supports this as milk production was highest in the control diet of SFC at 38.0 kg/d when compared with the other treatment diets (Table 5). Jenkins et al. (2006) discussed various treatment methods of controlling milk composition through dietary manipulation, and we used these guidelines to maintain adequate amounts of milk fat and protein percentages to ensure the profitability of the cows receiving the liquid feed. Milk fat and protein percentages were fairly constant among the treatments, but we grant that due to such a small sample size and short periods, these numbers may not accurately reflect actual differences. A study completed in conjunction with this digestibility trial revealed a drop in milk protein percentage with LF, but not in overall protein yield, due to an increase in overall production (unpublished). Milk urea nitrogen (MUN) was also found to decrease with the smaller particle size of corn grain, which could be reflective of the lower ruminal ammonia concentrations discussed earlier.

Table 5. Animal performance, including dry matter intake (DMI), milk yield, milk fat, milk protein, and milk urea nitrogen (MUN).[1]

Item[2]	SFC	FGC	CGC	FGC + LF	CGC + LF
DMI, kg/d	24.7	24.9	24.2	24.6	24.7
Milk, kg/d[s]	38.0	36.1	35.7	36.0	35.9
Milk fat, %	3.62	3.31	3.65	3.43	3.53
Milk protein, %	2.87	2.84	2.97	2.77	2.78
MUN, mg/dl[P]	11.8	11.7	13.3	11.9	12.9

[1]SFC = Steam flaked corn, FGC = finely ground corn, CGC = coarsely ground corn, and LF = liquid feed.

[2]Contrasts: **Liquid feed** (CGC, FGC vs CGC+QLF, FGC+QLF), **L** = P < 0.05, **l** = P < 0.10; **Particle size** (CGC, CGC+QLF vs FGC, FGC+QLF), **P** = P < 0.05, **p** = P < 0.10; **SFC vs dry corn** (SFC vs CGC, FGC, CGC+QLF, FGC+QLF), **S** = P < 0.05, **s** = P < 0.10; and **Interaction L vs P, LP** = P < 0.05, **lp** = P < 0.10.

Conclusion and Implications

In conclusion, we could not accept our hypothesis that the sugars found in the LF would maintain or improve measures of ruminal fermentation and diet digestibility to a greater degree when corn is coarsely compared to finely ground. However, the SFC and FGC seemed to be more rapidly fermented in the rumen, without adversely affecting intake or digestibility. The LF appeared to be more beneficial with the FGC than the CGC. The LF could serve as an alternate method of increasing ruminal fermentation of FGC compared with SFC in order to increase milk production in lactating dairy cattle.

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